CAAM 336

DIFFERENTIAL EQUATIONS IN SCIENCE AND ENGINEERING

Fall 2020 · Rice University

Lectures:	Sect 901 (Bencomo), MWF 1:30pm - 2:25pm, Zoom ID: 922 1241 7998, Passcode: 3o262f Sect 002 (Protasov), MWF 8:30am - 9:25am, Zoom ID: 998 5257 5882, Passcode: 3a659v
Instructor:	Mario Bencomo (mjb6@rice.edu) Office hours: Thursdays 2:30pm - 3:30pm, Zoom ID: 984 6089 6235, Passcode: 8q195f
Instructor:	Anastasiya Protasov (anastasiya.n.protasov@rice.edu) Office hours: Thursdays 11am - 12pm, Zoom ID: 994 5784 0128, Passcode: 2c443u
Teaching Assistant:	Christina Taylor (cgt3@rice.edu)
Webpage:	https://canvas.rice.edu/courses/34664

Course summary

This course introduces several approaches, numerical and analytical, to solving partial differential equations. Spectral, finite element and finite difference methods will be discussed in detail, in particular for solving the heat equation. These techniques will rely on some foundations of abstract mathematical ideas such as vector spaces, inner products, bases of orthonormal eigenvectors, projections, etc. Fundamental concepts of computational mathematics, such as convergence and approximation order, will also be explored primarily through MATLAB.

Learning outcomes

- ◇ Mathematical literacy, in particular in the field of differential equations.
- ◇ Theoretical and practical knowledge for solving PDEs via several analytical and numerical methods.
- ◇ Working knowledge of LaTeX.

Prerequisites

Student should be able to write basic MATLAB programs, and be comfortable with vector calculus and elementary vector and matrix operations. More formally:

- ◇ CAAM 210, introduction to engineering computation, and
- ◇ MATH 212, multivariable calculus.

Students are expected to have access to a computer/laptop with MATLAB and uninterrupted connection to the internet.

Text

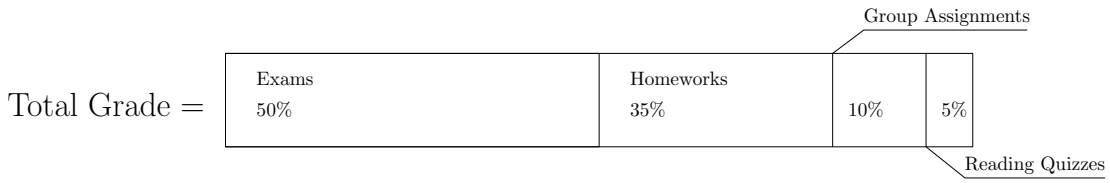
- ◇ Mark S. Gockenbach, *Partial Differential Equations: Analytical and Numerical Methods*, SIAM, Philadelphia, 2011, 2nd edition.
- ◇ Lecture notes available on CANVAS course page and updated as semester progresses.

Zoom Lectures

- ◇ Lectures for both sections will be recorded live using Zoom and posted on CANVAS.
- ◇ Students should mute both video and audio during passive participation.
- ◇ Questions are encouraged and will be addressed (for online students) with the "raise hand" or chat feature on Zoom, at which point the student may directly (with audio) or via chat ask a question.
- ◇ Students are expected to complete relevant reading assignments ahead of lectures.
- ◇ Attendance is highly recommended though not enforced. Instructor reserves right to enforce attendance later in the semester, especially if unjustified low attendance is observed.

Assignments and Grades

◇ Total grade breakdown:



◇ Letter grades are assigned based on standard grade distributions.

◇ *Exams:* Four exams will be administered throughout the semester (including finals week) as pledged "take-home" assignments similar to homeworks. Each exam is equally weighted towards the final grade.

◇ *Homeworks:* Weekly assignments consisting of theoretical and computational problem sets. Collaboration is strongly encouraged, however, submitted write-up must be individual's own work; see honor code policy below for a statement on plagiarism.

- ▶ Posted every Friday and due the following Friday before 11:59PM (CST), unless stated otherwise.
- ▶ Homeworks (and exams) are to be submitted via CANVAS as a single PDF file, typed up using a LaTeX editor.

◇ *Group Assignments:* Groups will be assigned in the first week of classes by the instructor using information from the *beginning of the semester survey*. These assignments will be administered online through CANVAS and primarily consist of group discussion questions designed to prime students for homework assignments as well as self-assessment. Groups should meet up (virtually or in-person) for discussions and rotate weekly on a representative in-charge of writing and submitting the group response. It is the students' responsibility to manage their group and complete assignments. Contact the instructor in case of serious group issues or if group shrinks to two or less members due to students dropping out.

- ▶ Posted every Wednesday and due the following Wednesday before 11:59PM (CST), unless stated otherwise.

◇ *Reading Quizzes:* CANVAS administered quizzes prior to lectures to ensure students are completing reading assignments. These quizzes also serve as a diagnostic tool for the instructor, and help improve students' efficiency in completing homework assignments.

- ▶ Made available on a weekly bases, every previous Thursday.
- ▶ Deadlines are
  - ∗ on 12:00PM (CST) on the day of respective lecture for Section 901
  - ∗ on 6:00AM (CST) on the day of respective lecture for Section 002

◇ Typical work week:

Sunday	
Monday	• reading quiz, 12:00PM (CST) for Section 901 and 6:00AM (CST) for Section 002 • lecture
Tuesday	
Wednesday	• reading quiz, 12:00PM (CST) for Section 901 and 6:00AM (CST) for Section 002 • lecture • group assignment, 11:59PM (CST) • group assignment for next week made available
Thursday	• reading quizzes for next week made available
Friday	• reading quiz, 12:00PM (CST) for Section 901 and 6:00AM (CST) for Section 002 • lecture • homework, 11:59PM (CST) • homework for next week made available
Saturday	

Remark: Total grade computed for homeworks, group assignments, and reading quizzes will be proportional to the assigned points, respectively.

Communication Plan

- ◇ CANVAS *Announcements* will be used to communicate in mass with the entire course on updates and appropriate course content.
- ◇ CANVAS *Discussions* will be used as a means for students to pose content related questions to the instructor as well as the rest of the class. Students are welcomed to contribute to discussions by asking or answering questions, but it will not be mandatory nor a component of their grade.
- ◇ Instructors and the TA will hold office hours throughout the semester.
- ◇ As always, email is the preferred and reliable line of communication with the instructor for individual matters. Keep in mind that an immediate reply may not be guaranteed outside of working hours (9am-5pm weekdays).
- ◇ In general, students should not be contacting graders whatsoever. Moreover, students should not contact the TA with regards to grades.

Policies and Exemptions

- ◇ *Late Assignments*
  Assignment time-lines are constructed to be manageable and provide structure that reinforces the lecturing schedule. For this reason, late submissions are generally not accepted. The following are some exemptions:
  - ▸ In the case of non-LaTeX homework submissions, total penalty will be computed as
    $$\text{penalty} = \min(40\% + x \times 10\%, 100\%)$$
    where x is the overall number of non-LaTeX homework submissions. For example, the third non-LaTeX submission would incur a 70% penalty.
  - ▸ Exemptions due to the health reasons will be considered on a case by case basis. Please contact the instructor as soon as possible.
- ◇ *Honor Code Violations and Plagiarism*
  - ▸ It is an honor code violation to submit code or solutions which have, in all or in part, been copied from another student or other non-sanctioned sources.
  - ▸ It is an honor code violation to consult solutions from previous sections of this class or any other solutions manual.
  - ▸ When collaborating on permissible assignments, we suggest that students avoid interchanging finalized solutions but instead share and discuss the mathematical concepts and their problem solving approach in order to avoid issues with plagiarism.
- ◇ *Title IX Statement*
  Rice University cares about the wellbeing and safety of students. Rice encourages any student who has experienced an incident of harassment, pregnancy discrimination, gender discrimination, or relationship, sexual, or other forms interpersonal violence to seek support through the SAFE Office. Students should be aware when seeking support on campus that most employees, including ourselves, as the instructors/TA, are required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to Title IX professionals on campus who can act to support that student and meet their needs. For more information, please visit safe.rice.edu or email titleixsupport@rice.edu.
- ◇ *DSS Accommodations*
  Any student with a disability requiring accommodation in this course is encouraged to contact the instructor during the first week of class, and also to contact Disability Support Services in the Ley Student Center.

Tentative Weekly Schedule: The following schedule is intended to give a general idea of the progression of the course. The topics for each week are tentative and subject to change with advance notice. Please see `https://registrar.rice.edu/calendars/fall20` for a more thorough list of University-wide important dates.

Week 1: August 24th - 28th	Introduction to CAAM 336; Classification of differential equations; Derivation of heat equation.
Week 2: August 31st - September 4th	Introduction to vector spaces; Linear independence, basis and dimension; Linear operators and their range.
Week 3: September 7th - 11th	**No class on Monday**; Null space of linear operators; Introduction to inner product spaces and orthogonality.
Week 4: September 14th - 18th	Projection theorem; Application of projection theorem: Gram-Schmidt process; Spectral properties of symmetric linear differential operators.
Week 5: September 21st - 25th	Eigenpairs of steady state heat equation with homogeneous Dirichlet boundary conditions; Spectral method applied to abstract linear problem; Fourier sine series.
Week 6: September 28th - October 2nd	Spectral method for solving steady-state heat equation with homogeneous Dirichlet and Neumann boundary conditions, inhomogeneous boundary conditions.
Week 7: October 5th - 9th	Spectral method for solving time-dependent heat equation.
Week 8: October 12th - 16th	Introduction to Finite Element Method; Strong and weak formulations, Galerkin approximation; Space of continuous piecewise linear functions.
Week 9: October 19th - 23rd	Finite Element Method for steady-state heat equation with homogeneous and inhomogeneous Dirichlet boundary conditions.
Week 10: October 26th - 30th	Finite Element Method for steady-state heat equation with homogeneous and inhomogeneous Neumann boundary conditions; Finite Element Method for time-dependent heat equation.
Week 11: November 2nd - 6th	Introduction to the finite difference method; Proving order of finite difference approximations.
Week 12: November 9th - 13th	Finite difference method for boundary value problems; Numerical convergence rates of finite difference method; Finite difference method for steady-state heat equation with Neumann boundary conditions.
Week 13: November 16th - 20th	Finite difference method for steady-state heat equation with variable coefficients; Finite difference method for time-dependent heat equation.

Addendum

- Starting with HW8 and Exam2, typing up Homework and Exams will be optional.
- For Exam2, you are welcome to submit a combination of typed-up and handwritten work, but as a single document. For the rest of assignments you need to choose whether to submit a typed-up or handwritten work.
- Group assignments are still required to be typed up.
- Standard of completeness and correctness for handwritten assignments will be higher than for typed assignments:
  - All submissions must consist of a single PDF. Multiple files or other formats will not be accepted.
  - You will be penalized for not including relevant work/computations.
  - You are responsible for making the submissions legible. We will penalize or reject altogether (in extreme cases) for issues with legibility. Issues that may affect legibility of submission include bad handwriting or presentation of work, or poor quality of digital copy.
  - You are responsible for making time to scan and upload submissions. Late assignments due to issues with scanning and formatting at the last minute will not be considered.
  - Any assignment with a Matlab component will still require students to include their code, along with specified plots.